FIFTH QUARTERLY PROGRESS REPORT
(May 1984 - December 1984)

on

DEVELOPMENT OF SAFETY CRITERIA FOR EVALUATING CONCRETE TIE TRACK IN THE NORTHEAST CORRIDOR
(CONTRACT DTFR53-83-C-00009)

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION

MARCH 4, 1985

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1.0 SUMMARY

- Tests of track degradation rates under impact loads were begun in June 1984 with the installation of simulated engine burns on concrete tie track at the Transporation Test Center (TTC). These tests are still in progress.

- Field experiments to verify analytical predictions of concrete tie track strength were conducted at TTC during August 1984. Rail force/deflection tests were run with up to 18 clip-pairs and insulators removed

- Refinements were made to the rail deflection program RAILDEF, and the rail buckling program TBTRACK. Good validation of RAILDEF was achieved by comparing results with the TTC test data. Rail buckling was not induced at TTC due to limited evaluated temperatures, so that direct validation of TRTRACK was not possible.

- Problems with the "track walker" data management program were corrected, and the data base for all four surveys and four test sites was completed. Track component event clusters and correlations between rail running surface anomalies and component events (fastener fallouts, pad displacements, etc) were then determined by interactive manipulation of the data base.

- Results of the program to date were presented at FRA to an audience of FRA, AMTRAK and NECIP personnel on February 7, 1985. This presentation included the remedial projects, track survey, TTC tests, and computer validation tasks.

2.0 PROBLEMS AND DELAYS

- The program was conducted at a reduced level of effort while contractual negotiations on Contract Modification No. 2 were underway. This delayed the project schedule by several months.
- Track degradation tests at TTC have progressed much more slowly than anticipated due to the limited running of the FAST train over the past 8 months. Only 18 MGT have been accumulated to date.
- A serious problem in updating the "track walker" data base with new survey results was discovered in late December. This required program changes and reloading all four surveys, and resulted in a 1-1/2 month delay.
- A change in key project personnel at Battelle caused some additional delays in report preparations.
- Technical problems have been corrected and program final reports will be issued by the end of March.

3.0 FRA ACTION ITEMS

- Forward results of TTC track degradation tests to BCL for inclusion in the final report, as quickly as possible.

4.0 PROJECTED ACTIVITY FOR SIXTH QUARTER

- Complete Remedial Programs Report and Final Report as quickly as possible.

5.0 TECHNICAL DISCUSSION

Task 1. Track Condition Assessment

The results of the last of four surveys of the four NEC test sites were forwarded to Battelle by the fourth quarter of 1984. These track walker data were loaded into the existing data base (the first two surveys) as shown in the flow chart of Figure 1. A serious problem with the data base was discovered when tables of numbers of track component faults for individual surveys at each site were prepared. Numbers given in the tables previously prepared for Surveys 1 and 2 no

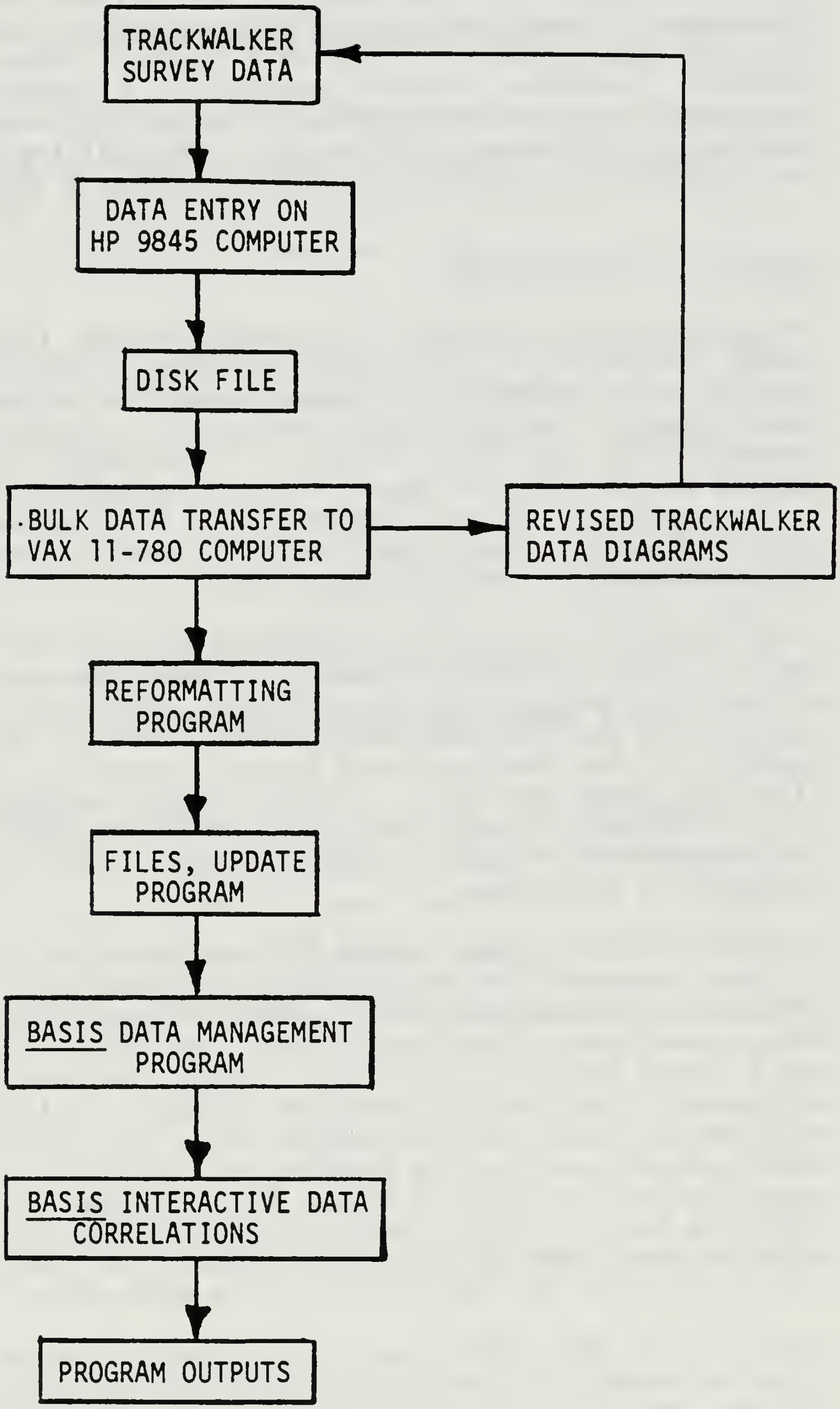


FIGURE 1. FLOW CHART FOR DETAILED TRACK SURVEY DATA REDUCTION AND MANAGEMENT

longer corresponded in some cases to the final data base. Investigation of these discrepancies showed that the update program (Figure 1) was storing new data in the first data location for a given tie number, rather than the first empty data location. Therefore, old data were lost in a random fashion. The reformatting and update programs were modified to correct this fault, but the complete data base had to be reloaded. Fortunately, about half the data base (Surveys 1 and 2) was stored in the intermediate format on magnetic tape.

Results of Track Surveys

The results from all four track walker surveys for the four test sites were loaded into Battelle's BASIS data management program and verified by comparing specific track component fault occurrences with the numbers previously observed. Descriptions of the four test sites, each including between 10,475 to 15,450 concrete ties, are given in Table 1. Individual track component faults were entered for specific tie sequence numbers by the descriptive code given in Table 2. An example of the data storage format for three successive ties in Site 1 is given in Figure 2. The pattern of faults found in Survey 1 near the engine burn (EB) at Tie #33 is shown in Figure 3.

Clip, insulator, pad and tie performance over the four surveys is summarized for the four sites in Tables 3 through 6. These tables reflect the revised estimates of cumulative tonnage over the test sites, which are noted in Table 1. In these tables, clip and insulator event numbers represent new occurrences, where maintenance (QC) has been performed between surveys in Sites 1, 2 and 3 to replace clips and broken insulators. Only a partial maintenance was performed within Site 5, between Surveys 3 and 4, so that some cumulative effect is included. Pad, shoulder/insert and tie faults are cumulative in number, since these were to corrected in maintenance.

The BASIS data management system was used to explore some of the characteristics of track component faults, particularly clustering of events and correlations between rail surface anomalies (welds, joints, etc.) and component faults, or between one type of fault and another. An example of this is given in Tables 7 and 8, where the number of fastener events (fasteners moving or out) associated with specific rail surface anomalies is shown. In the case of welds and joints, which occur predominantly on one rail only, not in pairs, there are significantly more fastener events on the opposite rail within ± 1 tie of the impact load. An example of this is given in Figure 4. This effect is gradually lost 3 to 5 ties away from the rail joint or weld. In the case of engine burns, which occur more often in pairs opposite one another, roughly the same number of fasteners moving out are found on the same rail as on the opposite rail within ± 1 tie.

Site 1 (with the older relay rail) showed 32 percent of the fastener events occuring within ± 5 ties of a rail running surface anomaly. The other test sites, however, showed less than 11 percent of the fastener events occuring within ± 5 ties of an anomaly. This indicates that clip movement and fallout is as much a function of track (particulary tie) vibrations due to passing rough wheels as it is a function of rail running surface roughness.

TABLE 1. DESCRIPTION OF DETAILED TRACK COMPONENT SURVEY TEST SITES

<u>Test Site 1</u> - Bush to Aberdeen, Track 2, MP 69-64 (northbound). Curves - MP 66.5 to 66.1, 0°32' LH; MP 65.3 to 64.6, 1°00' RH. Installed July 1980, about 5.4 MGT/yr. older relay rail.

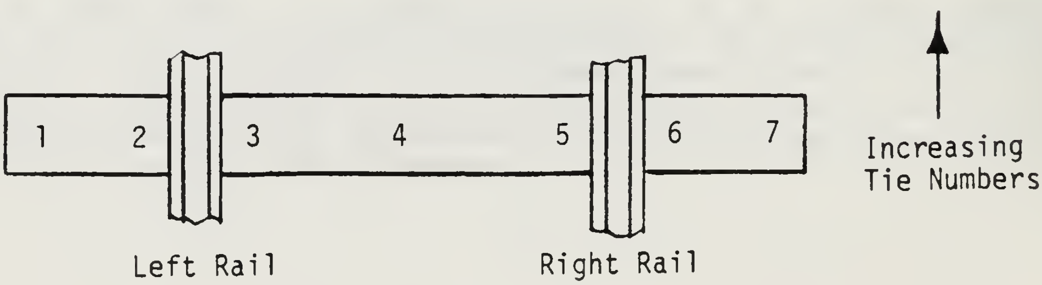
<u>Test Site 2</u> - Davis to Northeast Track 4 (renumbered Track 3, June 1983), MP 44-48 (southbound). Curves - MP 46.8 to 47.3, 1°00' RH; MP 44.0 to 44.7, 0°14' RH. Installed August - September 1980, about 7.5 MGT/yr.

<u>Test Site 3</u> - Davis to Northeast, Track 3, MP 44 - 48 (southbound). Curves - (same as Site 2). Installed August - September 1980, about 16 MGT/yr. Renumbered Track 2, June 1983, switched direction to primarily northbound passenger, about 8 MGT/yr.

<u>Test Site 5</u> - Grundy to Morris, Track 2, MP 65 - 59 (northbound). Installed April 1982, about 3.4 MGT/yr (primarily passenger). New softer (Trelleborg) pads. Curves - MP 64.7 to 64.3, 0°43' LH; MP 62.0 to 61.3, 0°45' RH; MP 60.6 to 60.3, 0°25' RH.

TABLE 2. DESCRIPTION OF TRACK COMPONENT SURVEY EVENT CODES

Code	Description
CT1	Concrete tie center crack
CT2	Concrete tie insert crack
CT3	Concrete tie longitudinal crack
CT4	Concrete tie torsional crack
DT	Damaged tie
EB	Engine burn
EBB	Engine burn, break (in rail)
FI	Fastener improperly installed
FM	Fastener moving (>½" inside insert)
FN	Fastener, new
FO	Fastener out
FW	Field weld
FWB	Field weld, battered
FWC	Field weld, crowned
GC	Grade crossing (removed)
IB	Insulator broken
II	Insulator improperly installed
IL	Insulator loose
IM	Insulator missing
IN	Insulator, new
J	Joint
J .	Joint with depth measured
JI	Joint, insulated
JIB	Joint, insulated, battered
JIC	Joint, insulated, crowned
JM	Joint, mechanical
JT	Joint, temporary
PB	Pad, broken
PD	Pad, displaced
PM	Pad missing
S	Skewed tie
SF	Shoulder/insert fractured or broken
SL	Shoulder/insert loose
SM	Shoulder/insert missing
T	Transition, wood to concrete ties
TB	Transition, beginning
TE	Transition, end
LOC	Location



0. TIE SEQUENCE NR	9444
2. SITE NR	1
3. MILEPOST NR	67.57
4. SECTION NR	11
5. TIE NR	33
12. DEFECT LOCATION-1	2
13. DEFECT CODE-1	FO
14. SURVEY NR-1	1
16. DEFECT LOCATION-2	3
17. DEFECT CODE-2	FO
18. SURVEY NR-2	1
20. DEFECT LOCATION-3	3
21. DEFECT CODE-3	EB
22. SURVEY NR-3	1
23. DEFECT QUANTITY-3	.050

0. TIE SEQUENCE NR	9445
2. SITE NR	1
3. MILEPOST NR	67.57
4. SECTION NR	11
5. TIE NR	34
12. DEFECT LOCATION-1	2
13. DEFECT CODE-1	FO
14. SURVEY NR-1	1
16. DEFECT LOCATION-2	3
17. DEFECT CODE-2	FO
18. SURVEY NR-2	1

0. TIE SEQUENCE NR	9446
2. SITE NR	1
3. MILEPOST NR	67.57
4. SECTION NR	11
5. TIE NR	35
12. DEFECT LOCATION-1	2
13. DEFECT CODE-1	FO
14. SURVEY NR-1	1
16. DEFECT LOCATION-2	2
17. DEFECT CODE-2	FM
18. SURVEY NR-2	3

FIGURE 2. EXAMPLE OF TRACK SURVEY DATA STORAGE FORMAT IN <u>BASIS</u> DATA MANAGEMENT PROGRAM

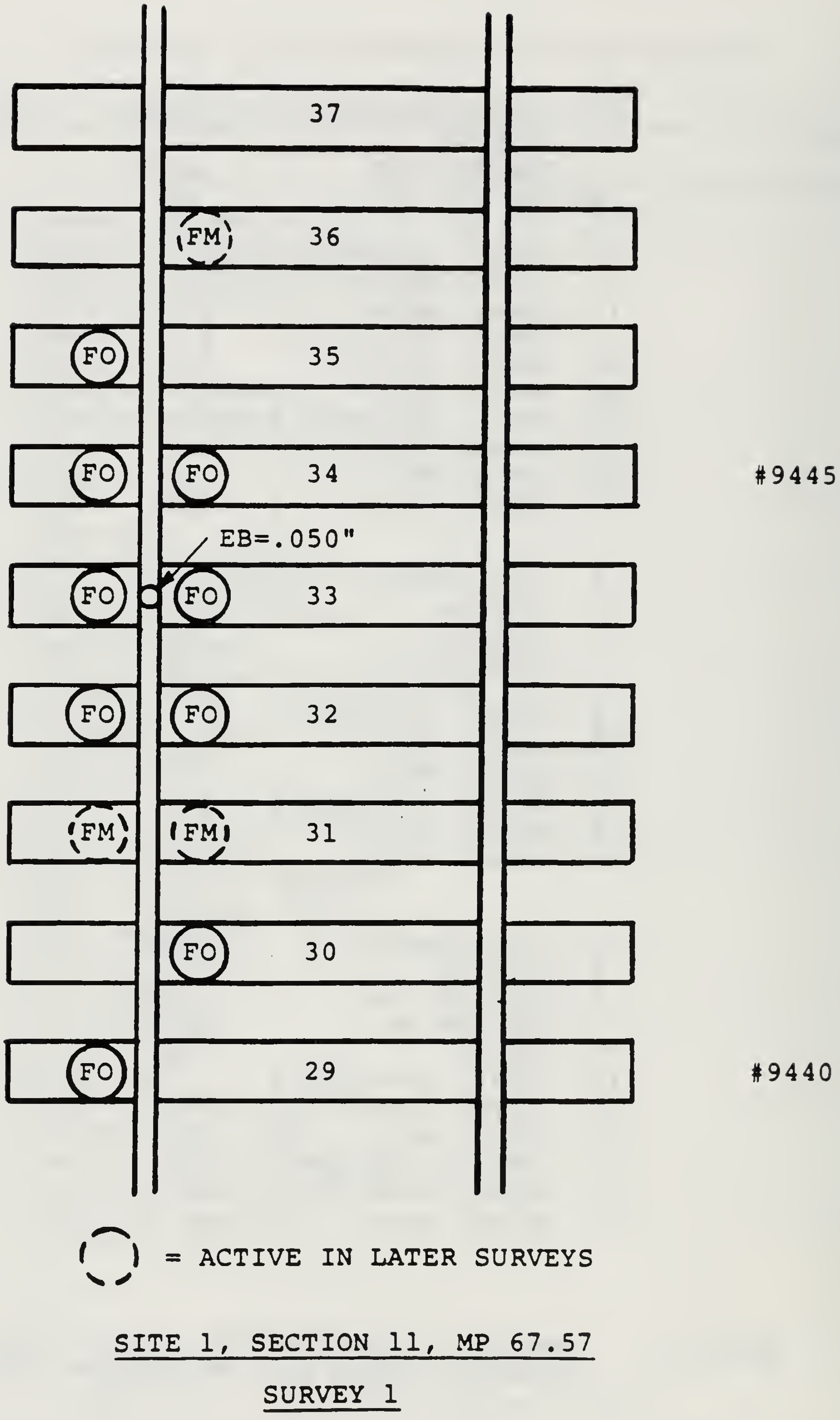


FIGURE 3. EXAMPLE OF TRACK COMPONENT FAULTS OBSERVED DURING FIRST SURVEY OF TEST SITE #1, SECTION #11

TABLE 3. SUMMARY OF TRACK COMPONENT PERFORMANCE FOR SITE 1

(a) Clip Performance#

Survey	Total Tonnage (MGT)*	Clips Out	%	% Per MGT	Clips Moving	%	% Per MGT
1	10.8	351	0.67	--	287	0.55	--
2	13.1	337	0.65	0.29	1213	2.33	1.01
3	16.7	206	0.40	0.11	1306	2.51	0.70
4	20.3	401	0.77	0.21	1759	3.38	0.97

(b) Insulator# and Pad Performance

Survey	Total Tonnage (MGT)	Insulators Broken or Missing	%	% Per MGT	Pads Displaced, Broken or Missing	%	% Per MGT	Insulators Installed Incorrectly
1	10.8	238	0.46	--	5	0.02	--	163
2	13.1	235	0.45	0.20	5	0.03	0.001	1
3	16.7	92	0.18	0.05	12	0.05	0.003	0
4	20.3	1	<0.01	<0.01	14	0.05	0.003	0

(c) Tie Performance

Survey	Total Tonnage (MGT)	Shoulder/ Insert Loose, Broken or Missing	%	% Per MGT	Cracked Ties	Damaged Ties	Skewed Ties
1	10.8	7	0.013	0.0012	9	6	0
2	13.1	29	0.056	0.0042	11	6	17
3	16.7	52	0.100	0.0060	15	6	26
4	20.3	78	0.150	0.0074	15	6	39

Total of 13,025 ties in site

* Estimated cumulative since track installed.
\# Maintenance (QC) performed between surveys.

TABLE 4. SUMMARY OF TRACK COMPONENT PERFORMANCE FOR SITE 2

(a) Clip Performance#

Survey	Total Tonnage (MGT)*	Clips Out	%	% Per MGT	Clips Moving	%	% Per MGT
1	14.1	26	0.06	--	206	0.49	--
2	17.8	37	0.09	0.02	311	0.74	0.20
3	23.1	173	0.41	0.08	467	1.11	0.21
4	28.4	152	0.36	0.07	643	1.53	0.29

(b) Insulator# and Pad Performance

Survey	Total Tonnage (MGT)	Insulators Broken or Missing	%	% Per MGT	Pads Displaced, Broken or Missing	%	% Per MGT	Insulators Installed Incorrectly
1	14.1	40	0.10	--	0	--	--	8
2	17.8	59	0.14	0.04	9	0.04	0.002	0
3	23.1	18	0.04	0.01	32	0.15	0.007	0
4	28.4	0	0	0	38	0.18	0.006	0

(c) Tie Performance

Survey	Total Tonnage (MGT)	Shoulder/ Insert Loose, Broken or Missing	%	% Per MGT	Cracked Ties	Damaged Ties	Skewed Ties
1	14.1	8	0.019	0.0013	10	5	2
2	17.8	12	0.029	0.0016	15	8	57
3	23.1	14	0.033	0.0014	16	8	77
4	28.4	20	0.047	0.0017	18	8	81

Total of 10,475 ties in site

* Estimated cumulative since track installed.
# Maintenance (QC) performed between surveys.

TABLE 5. SUMMARY OF TRACK COMPONENT PERFORMANCE FOR SITE 3

(a) Clip Performance#

Survey	Total Tonnage (MGT)*	Clips Out	%	% Per MGT	Clips Moving	%	% Per MGT
1	31.3	157	0.37	--	1462	3.44	--
2	40.7	127	0.30	0.03	703	1.65	0.18
3	47.0	147	0.35	0.05	1518	3.57	0.57
4	51.7	260	0.61	0.13	1300	3.06	0.65

(b) Insulator# and Pad Performance

Survey	Total Tonnage (MGT)	Insulators Broken or Missing	%	% Per MGT	Pads Displaced, Broken or Missing	%	% Per MGT	Insulators Installed Incorrectly
1	31.3	662	1.56	--	0	0	--	112
2	40.7	102	0.24	0.03	4	0.02	0.0005	0
3	47.0	59	0.14	0.02	15	0.07	0.002	0
4	51.7	0	0	0	21	0.10	0.002	0

(c) Tie Performance

Survey	Total Tonnage (MGT)	Shoulder/ Insert Loose, Broken or Missing	%	% Per MGT	Cracked Ties	Damaged Ties	Skewed Ties
1	31.3	7	0.016	0.0005	4	4	0
2	40.7	13	0.031	0.0008	6	4	23
3	47.0	20	0.047	0.0010	9	4	44
4	51.7	23	0.054	0.0010	9	4	55

Total of 10,625 ties in site

* Estimated cumulative since track installed.
# Maintenance (QC) performed between surveys.

TABLE 6. SUMMARY OF TRACK COMPONENT PERFORMANCE FOR SITE 5

(a) Clip Performance#

Survey	Total Tonnage (MGT)*	Clips Out	%	% Per MGT	Clips Moving	%	% Per MGT
1	2.6	399	0.65	--	994	1.61	--
2	4.5	535	0.87	--	1150	1.86	--
3	6.5	438	0.71	--	1484	2.40	--
4	7.8	125	0.20	--	603	0.98	--

(b) Insulator# and Pad Performance

Survey	Total Tonnage (MGT)	Insulators Broken or Missing	%	% Per MGT	Pads Displaced, Broken or Missing	%	% Per MGT	Insulators Installed Incorrectly
1	2.6	888	1.44	--	132	0.43	0.16	15
2	4.5	286	0.46	--	427	1.38	0.31	0
3	6.5	133	0.22	--	575	1.86	0.29	0
4	7.8	0	0	--	605	1.96	0.25	0

(c) Tie Performance

Survey	Total Tonnage (MGT)	Shoulder/ Insert Loose, Broken or Missing	%	% Per MGT	Cracked Ties	Damaged Ties	Skewed Ties
1	2.6	2	0.003	0.0012	5	6	61
2	4.5	3	0.005	0.0011	8	7	72
3	6.5	6	0.010	0.0015	9	7	90
4	7.8	13	0.021	0.0027	10	7	94

Total of 15,450 ties in site

* Estimated cumulative since track installed.
\# Maintenance (QC) performed between surveys 2 and 3 MP 59-62, only. Percent per MGT cannot be calculated.

TABLE 7. OCCURRENCES OF FASTENER INCIDENTS* IN VICINITY OF WELD OR RAIL JOINT ANOMALIES--SITES 1, 2 AND 3

Welds, joints Location (Rail)	No.	Fasteners Moving or Out Location (Rail)	Total No. Ties	Total No. Failures	Number of Occurrences Within ±0 Ties	± 1 Tie	±3 Ties	±5 Ties
Right	197	Right	4149	6827	18	120	381	515
Right	197	Left	4377	6721	74	216	422	555
Left	211	Left	4377	6721	11	111	419	582
Left	211	Right	4149	6827	68	175	395	534

* Fasteners out or moving.

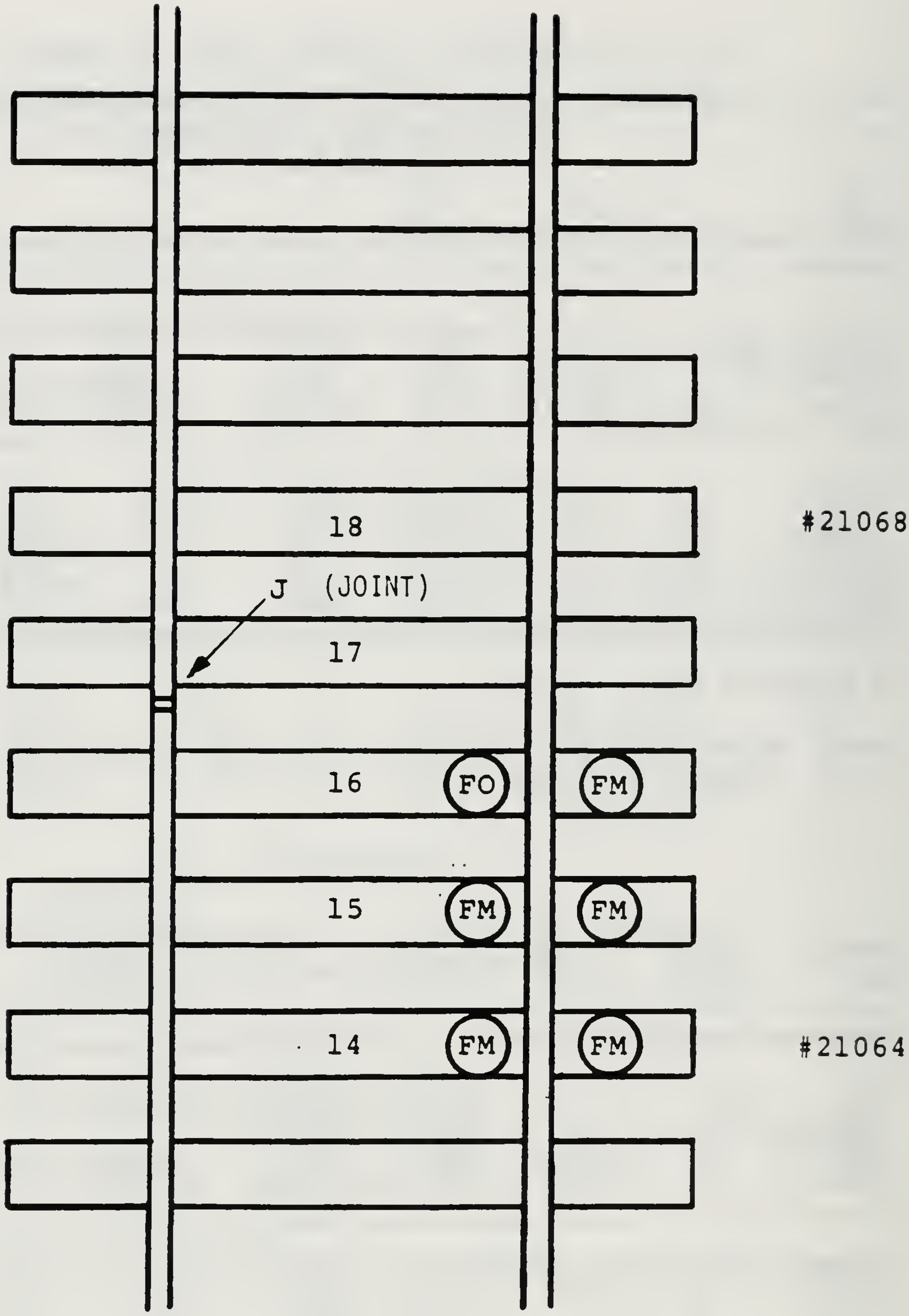
Note: Welds, joints at 400 ties, 410 unique values (only 10 occur opposite another at a given tie).

TABLE 8. OCCURRENCES OF FASTENER INCIDENTS* IN VICINITY OF ENGINE BURN ANOMALIES--SITE 1

Engine Burns Location (Rail)	No.	Fasteners Moving or Out Location (Rail)	Total No. Ties	Total No. Failures	Number of Occurrences Within ±0 Ties	±1 Tie	±3 Ties	± 5 Ties
Right	22	Right	1717	2846	37	86	117	145
Right	22	Left	1917	3013	27	83	121	163
Left	33	Left	1917	3013	46	103	149	177
Left	33	Right	1717	2846	40	89	113	155

* Fasteners out or moving.

Note: Engine burns at 44 ties, 55 unique values (11 occur opposite another at a given tie).



SITE 2, SECTION 8, MP 47.62

SURVEY 4

FIGURE 4. EXAMPLE OF FASTENER FAULT CLUSTERING ON RAIL OPPOSITE A RAIL JOINT OR BATTERED WELD

Several criteria for evaluating track strength from track walker survey data were examined. Four different criteria can be used, based on fastener fault clustering:

(1) Fasteners out, either side of the rail,
(2) Fasteners out, one side of the rail only,
(3) Fasteners moving or out, either side of the rail,
(4) Fasteners moving or out, both sides of the rail.

The numbers of locations of clusters, and the number of consecutive ties for a cluster, are shown for these different criteria in Table 9 for the Site 1, Survey 1 data. The most conservative is Criterion 3, which shows the largest number of missing or moving clips. From track strength considerations, however, Criterion 4 is more realistic in its definition, based on a pair of clips missing or moving at a given location. Fastener event patterns by Criteria 2, fasteners out on one side of the rail, are tabulated for the four sites in Table 10. Site 1 showed the highest incidence of fault clustering, probably due to the greater number of engine burns on the older relay rail. Similar results are seen in Table 11 for Critrion 4, fasteners moving or out on both sides of the rail. Sites 2 and 3 exhibited little evidence of fastener events in clusters, and generally lower percentages per accumulated tonnage (MGT of traffic). Site 5 had more random fastener movement and fallout, possibly due to installation problems with the softer pads. Fastener faults were evenly distributed on field and gage side of the rail except within Site 1, where roughly 35 percent more faults occurred on the gage side of the rail.

Insulator events (broken or missing) are given in Table 12, showing clusters on one side of the rail. Insulator failures occur in significantly greater numbers on the field side, probably because lateral impact loads from passing wheelsets are carried primarily by the field-side insulator into the shoulder. Field-side failures ranged from 1.7 to 3.5 times greater than gage-side failures. Site 3 (with the highest accumulated tonnage) and Site 5 (with possible installation problems) had the highest number of insulator failures at the time of Survey 1. These numbers dropped significantly in subsequent surveys as the result of maintenance. Few simultaneous occurrences of fastener and insulator faults were noted in the data base.

Shoulder/insert failures were found to occur two to three times more often on the field side in Sites 1 and 5, but were evenly distributed on field and gage side in Sites 2 and 3. There were relatively few shoulder/insert problems, with the highest numbers and percent per MGT found within Site 1. Only one cluster of three field-side shoulder/insert failures in a row was found, and this did not coincide with a fastener fault cluster.

Site 5 (with the more resilient Trelleborg pads) had the highest incidence of pads moving, damaged or missing. Site 5 also had the highest number of skewed ties. One of the busier component fault arrays within Site 5 is shown in Figure 5 clustered about a rail joint. Two of the skewed ties (47 and 48) are associated with clips out on both field and gage side and field-side insulators broken, all on one rail. Two other ties (56 and 57) that skewed by a later survey are associated with one clip out, three clips moving on one rail, in Figure 5.

TABLE 9. COMPARISON OF FASTENER SAFETY EVALUATION CRITERIA
SITE 1, SURVEY 1 TRACKWALKER RESULTS

Evalution Criteria		Total Number Ties	Total Number Fasteners	Number of Locations	Number Consecutive Ties
Fasteners out, either side of rail (FO)	- left rail	145	158	8	2
				4	3
				1	4
	- right rail	176	193	13	2
				1	3
Fasteners out, one side of rail (FO)	- left rail, field side	86	86	6	2
				1	4
	- gage side	72	72	4	2
				3	3
	- right rail, field side	104	104	8	2
	- gage side	89	89	4	2
Fasteners moving or out, either side of rail (FM or FO)	- left rail	308	326	18	2
				6	3
				2	4
	- right rail	292	312	22	2
				2	3
				1	4
Fasteners moving or out, both sides of rail	- left rail	18	36	1	3
	- right rail	20	40	2	2

TABLE 10. FASTENER EVENT PATTERNS IN TEST SITES--
FASTENERS OUT ON ONE SIDE OF RAIL

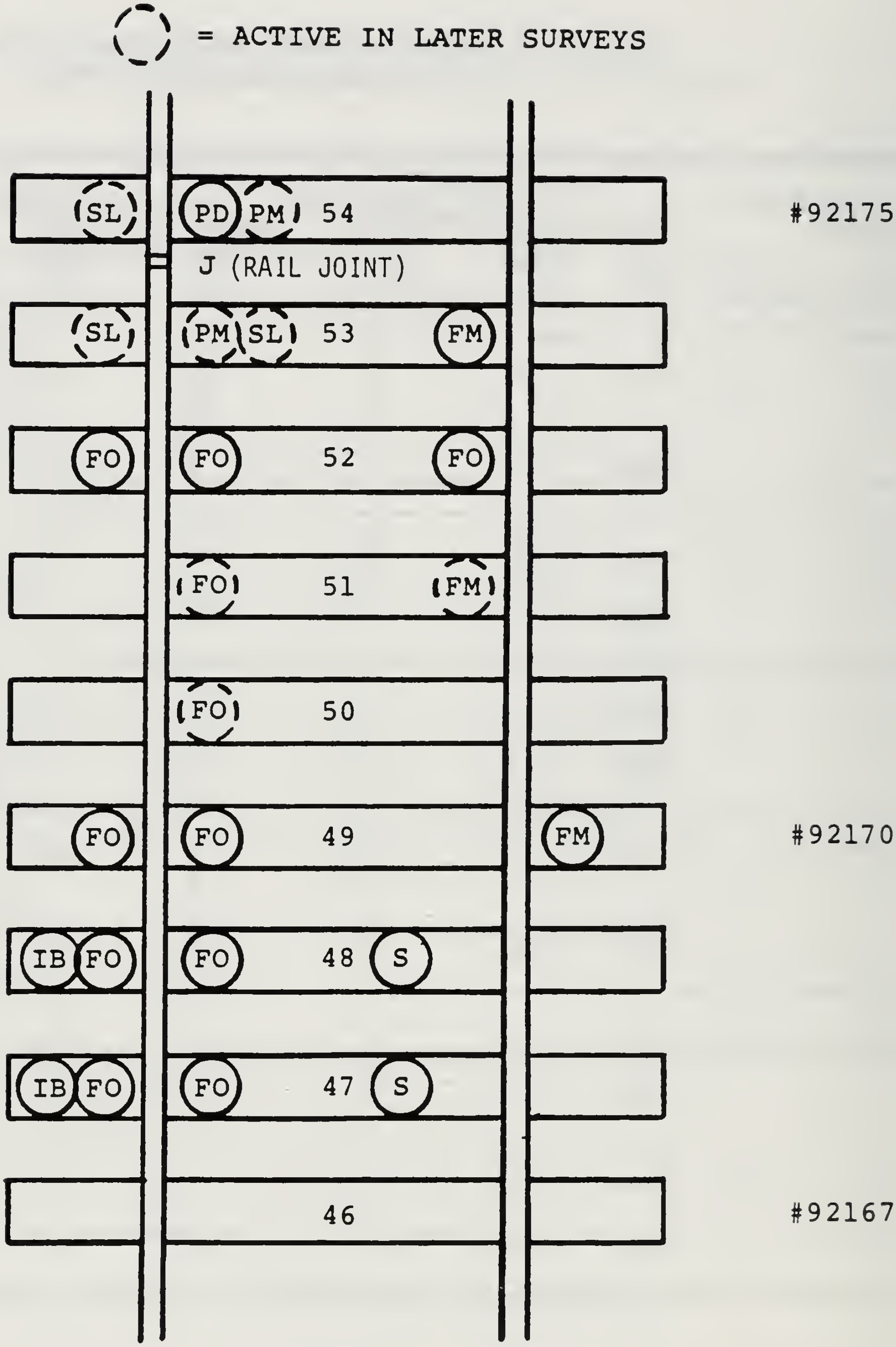
			Left Rail			Right Rail		
Site	Survey	Side of Rail	Total Number Ties	Number of Locations	Number of Consecutive Ties	Total Number Ties	Number of Locations	Numberof Consecutive Ties
1	1	Field	86	6 1	2 4	104	8	2
		Gage	72	4 3	2 3	89	4	2
2	1	Field	11	0	--	3	0	--
		Gage	1	0	--	11	1	2
2	4	Field	45	0	--	39	2	2
		Gage	45	2	2	23	0	--
3	1	Field	45	2	2	39	1	2
		Gage	40	1	2	33	2 1	2 3
3	3	Field	65	2 1	2 3	30	1	2
		Gage	29	1	2	23	1	2
5	2	Field	155	5 2	2 3	128	4	2
		Gage	126	1 1	2 3	126	1	2

TABLE 11. FASTENER EVENT PATTERNS WITHIN TEST SITES
--FASTENERS MOVING OR OUT ON BOTH SIDES OF RAIL

		Number of Ties		Left Rail		Right Rail	
Site	Survey	Left Rail	Right Rail	Locations	Consecutive Ties	Locations	Consecutive Ties
1	1	18	20	1	3	2	2
	2	32	16	1	2	0	--
	3	25	23	1	2	2	2
	4	45	41	2	2	4	2
2	1	1	1	0	--	0	--
	2	1	0	0	--	0	--
	3	5	2	0	--	0	--
	4	3	17	0	--	1	3
3	1	13	18	0	--	0	--
	2	2	5	0	--	0	--
	3	20	7	2	2	1	2
	4	16	14	0	--	0	--
5	1	26	5	1	2	0	--
	2	39	10	2	2	0	--
				1	3		
	3	40	12	0	--	0	--
	4	7	4	0	--	0	--

TABLE 12. INSULATOR EVENTS (BROKEN OR MISSING) IN TEST SITES--ONE SIDE OF RAIL

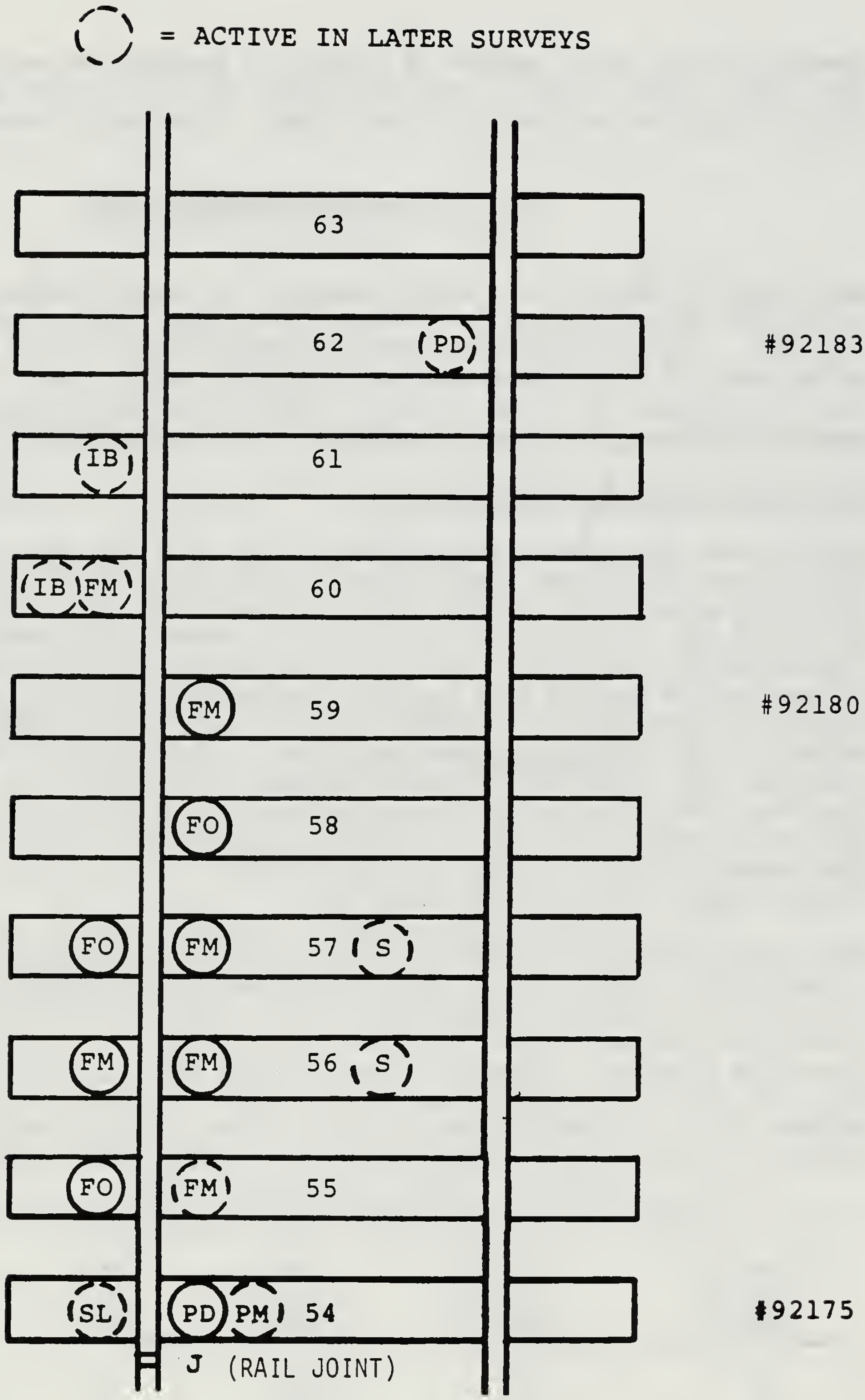
			Left Rail			Right Rail		
Site	Survey	Side of Rail	Total Number Ties	Number of Locations	Number of Consecutive Ties	Total Number Ties	Number of Locations	Numberof Consecutive Ties
1	1	Field	85	5	2	103	3	2
				1	4			
		Gage	22	2	2	31	1	2
2	1	Field	23	0	--	11	1	2
		Gage	1	0	--	5	0	--
2	4	Field	0	0	--	35	2	2
		Gage	3	0	--	8	0	--
3	1	Field	142	2	2	254	12	2
				1	3		2	3
		Gage	99	1	2	167	4	2
3	3	Field	13	0	--	35	2	2
		Gage	3	0	--	8	0	--
5	2	Field	158	3	2	83	1	2
		Gage	29	0	--	16	0	--



SITE 5, SECTION 14, MP 63.74

SURVEY 2

FIGURE 5. EXTENSIVE TRACK COMPONENT FAULT PATTERN NOTED IN SURVEY OF TEST SITE 5



SITE 5, SECTION 14, MP 63.74

SURVEY 2

FIGURE 5. (CONTINUED)

Comparable (and small) numbers of cracked or damaged ties were noted in all four test sites. Note, however, that the surveys did not include the careful examination of ties for hairline rail seat cracks in previous studies.

Task 2. Track Performance Limits

Experiments in support of the NEC Concrete Tie Safety Assessment were conducted at the AAR Transportation Test Center (TTC) near Pueblo, Colorado starting in June 1984. The objectives of these experiments were (1) to explore the degradation rates of track components under impact loading, and (2) to verify analytical predictions of track strength reduction with different combinations of damaged or missing fasteners, insulators, or shoulder/inserts.

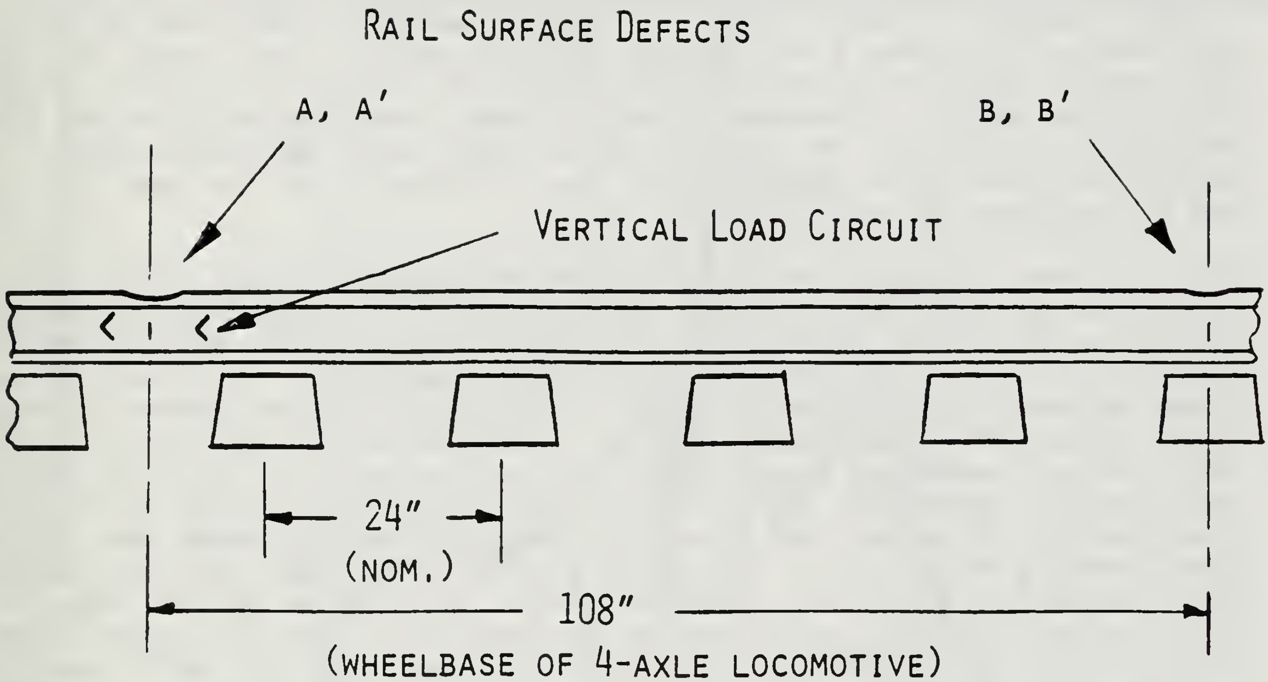
Track Degradation Experiments

This test was initiated by creating artificial rail surface anomalies to simulate engine burns and produce severe impact loads, up to 90,000 lb or greater. From laboratory experiments, impact loads in excess of 75,000 lb were determined to be sufficient to initiate a rail seat crack. The vehicle/track simulation model, Program IMPACT, was used to define the surface anomaly size and depth necessary to generate the desired load levels. Four patterns of four rail anomalies each, shown in Figure 6 for a typical pattern, were ground into the rail running surface of the tangent, concrete-tie track in Section 22 of the FAST loop. The anomalies were ground in a circular pattern representing the effect of a wheel burn from a 40-inch diameter locomotive wheel and a 108-inch wheelbase. Vertical wheel/rail load circuits were installed on the inside (left) rail under each mid-crib anomaly (Figure 6), and one instrumented (strain-gaged) tie was installed directly under a pair of rail anomalies.

The simulated engine burns were at first ground in on the plane of the track, but it was quickly noted that the worn running surface of the rail (approximately a 1:5 cant angle) put the anomalies at the extreme field side of the rail, where contact with the worn wheel profiles of the FAST train was minimal. The anomalies were therefore reground in line with the rail surface cant angle. Originally, the anomalies were ground in to achieve impacts ranging from 25 to 100 percent of the intended maximum 90,000-lb load. Considerable modification was necessary, probably due to the rail and FAST train wheel profile wear:

Percent of Maximum Impact	Initial Planned Depth, in	Final Anomaly Depth,	Mean Load (kips)	Maximum* Load (kips)
25	0.007	0.030	50	76
50	0.015	0.035	56	84
75	0.022	0.062	69	98
100	0.030	0.080	76	109

*At 3 Standard Deviations



RAIL SURFACE DEFECT ARRAY IN SECTION 22 (TTC)

FIGURE 6. PATTERN OF SIMULATED ENGINE BURN DEFECTS USED IN TRACK COMPONENT DEGRADATION RATE TESTS

The experiments were begun in June 1984 and, except for some deepening of the largest anomaly prior to the 4 MGT measurements, the anomalies have remained untouched and allowed to batter and change shape naturally under traffic. A plot of vertical wheel impact loading within the rail circuit influence zone under the largest anomaly is shown in Figure 7. Impact loading is seen to be basically a half-sine pulse of about 2 milliseconds duration, which is short enough to induce tie bending vibrations in the first three modes of transverse vibration: roughly 125, 330 and 650 Hz. Histograms of vertical peak loads from this site are shown in Figures 8 and 9 for the zero MGT (first runs) and 4 MGT measurements. The effects of deepening the anomaly can be seen in Figure 9. The few lower loads are due to empty cars in the FAST train.

The experiment proceeded more slowly than anticipated because of the limited running of the FAST freight train. Very little track degradation was observed during the first 6 MGT of accumulated tonnage: two clips on the inside rail at Tie 0097 came out, along with two clips at other locations. These were replaced after the track strength tests in August. As a result of the December presentations at the ASME Winter Annual Meeting, attention was focused on the relative merits of rail anomalies on one versus both rail surfaces. It was felt that the slow rate of degradation at the test site might be attributed to the phase relationships of second and third transverse tie bending modes when excited simultaneously at both rails. Anecdotes from the NEC surveys, later confirmed by the track walker data base, indicated greater activity on the rail opposite a single anomaly such as a rail joint or battered weld. For this reason, therefore, the outside (right) rail at Ties 96-101 (the 0.080-inch depth anomalies) was repaired, leaving anomalies only on the inside (left) rail.

Currently, the fastener fault pattern shown in Figure 10 exists at the 0.080-inch anomalies with an accumulated tonnage of 18 MGT. A little pumping and some dust around the ties has been noted. One additional gage-side clip was out at Tie 0121. No other problems such as tie cracking or shoulder/insert failures have been reported. Runs since about 15 MGT have been conducted without track lubrication, and more evidence of clip movement and ballast migration from cribs has been reported during these "dry" runs. This may be due to higher general track vibration levels, even on tangent track, during the unlubricated runs.

Track Strength Tests

Track strength tests were carried out in early August of 1984 to provide data for verification of Battelle's analytical models. These tests had two objectives: (1) to develop rail lateral deflection versus applied force for different numbers of fasteners (clips and insulators) missing, and (2) to test for rail buckling instability with missing fasteners and the uplift from an approaching railcar.

The TTC 605 car was used to apply simultaneous vertical and lateral loads to the rails through simulated wheel profiles and hydraulic rams at the midspan of the car. Vertical loads were first increased to 15,000 lb to represent the typical wheel loads of an Amcoach, and then lateral gage-spreading load was increased from zero to 20,000 lb and back to zero, with both the rail head and base lateral

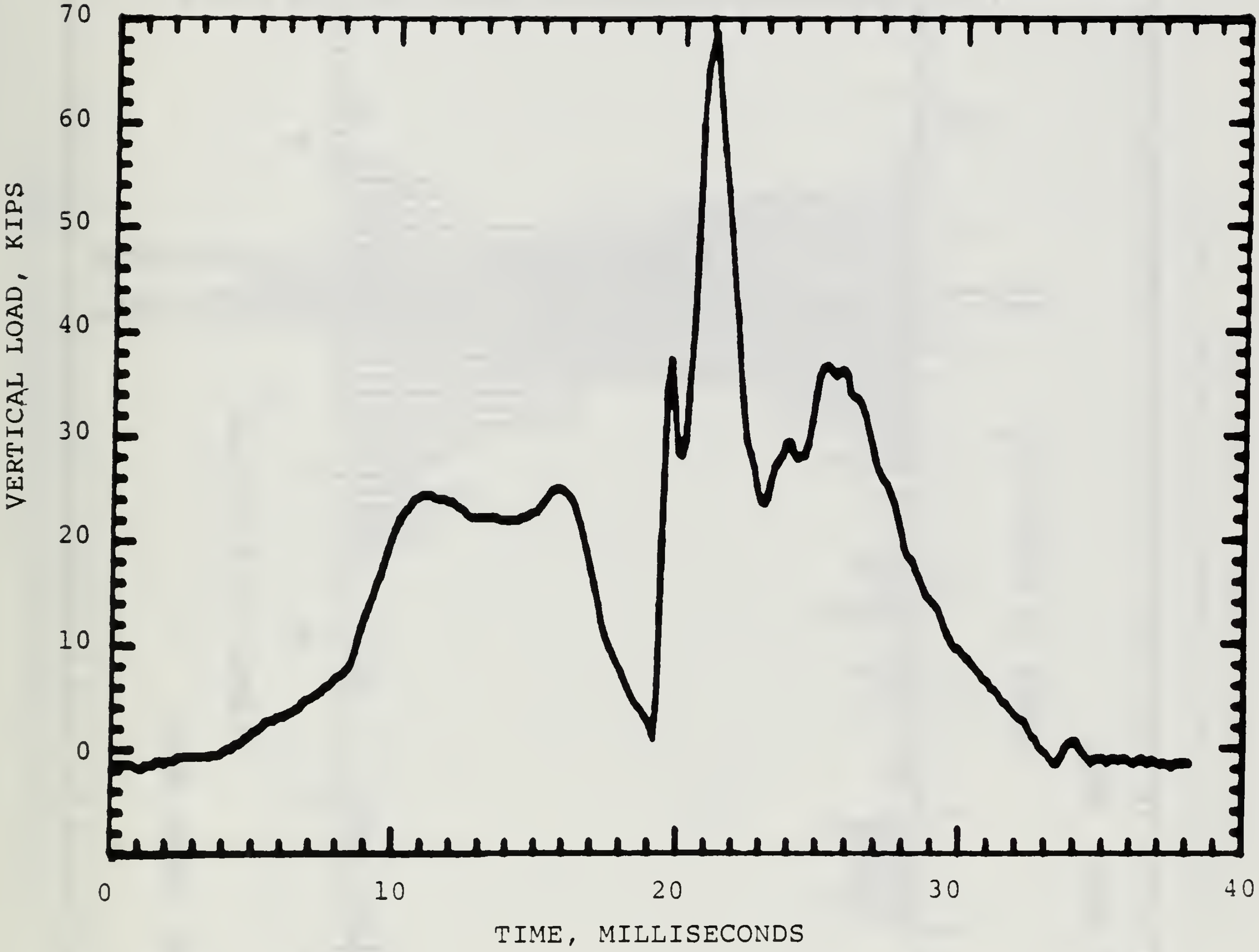


FIGURE 7. WHEEL IMPACT LOAD UNDER LEADING AXLE OF GP-40 LOCOMOTIVE, RAIL DIVOT DEPTH = 0.063" (96IVX)

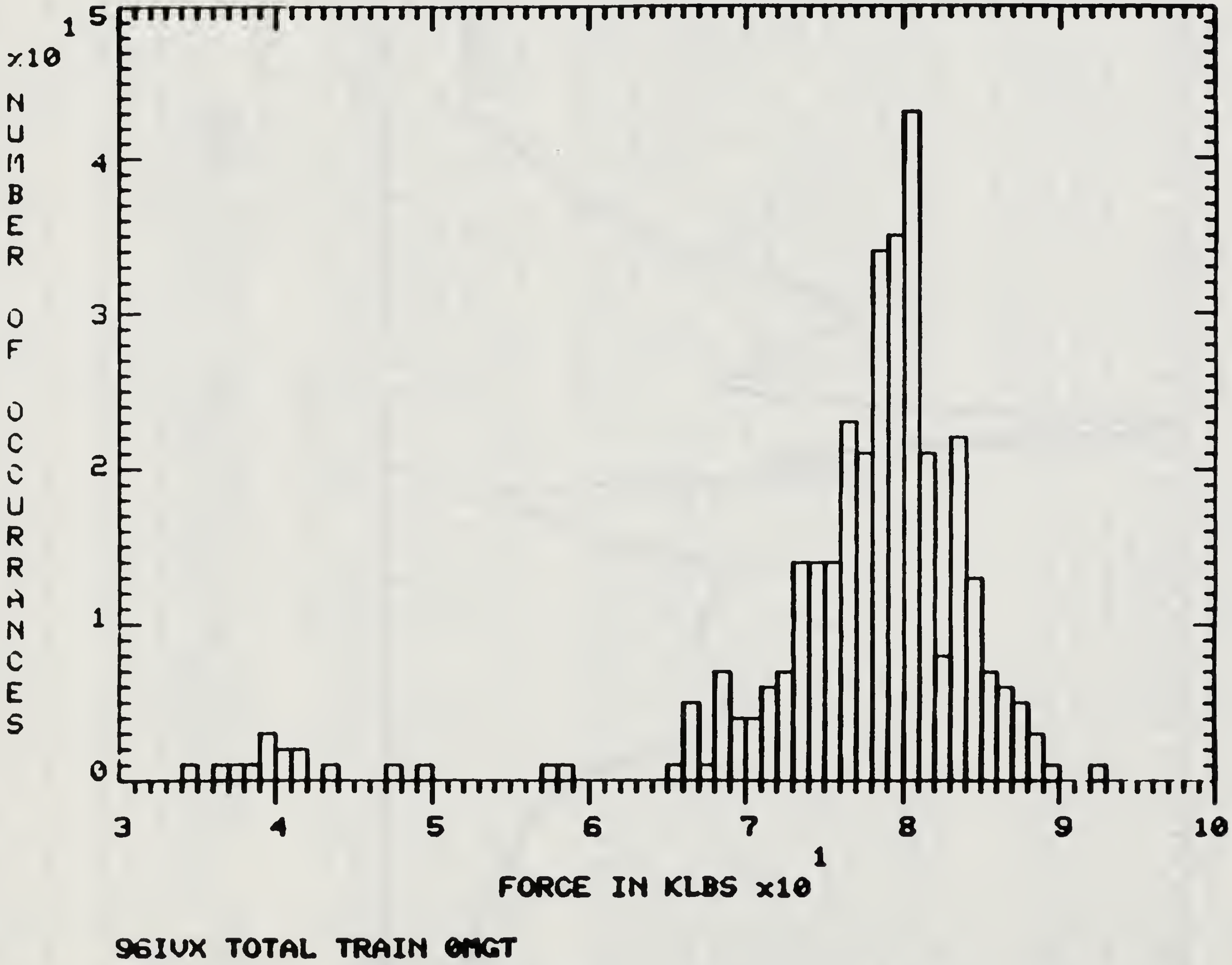


FIGURE 8. VERTICAL LOAD HISTOGRAM WITH ORIGINAL (.063") SIMULATED ENGINE BURN ON CONCRETE-TIE TRACK

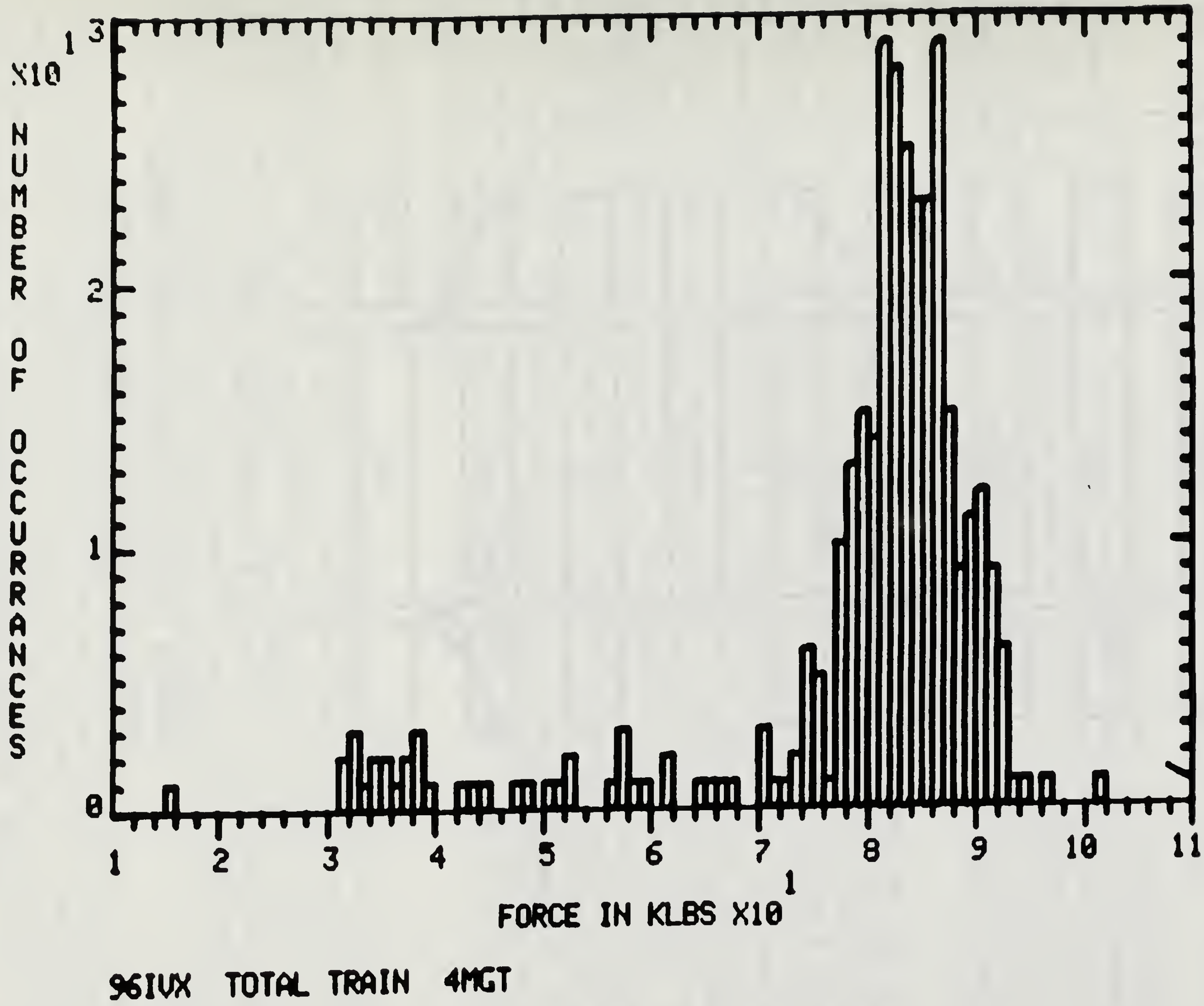
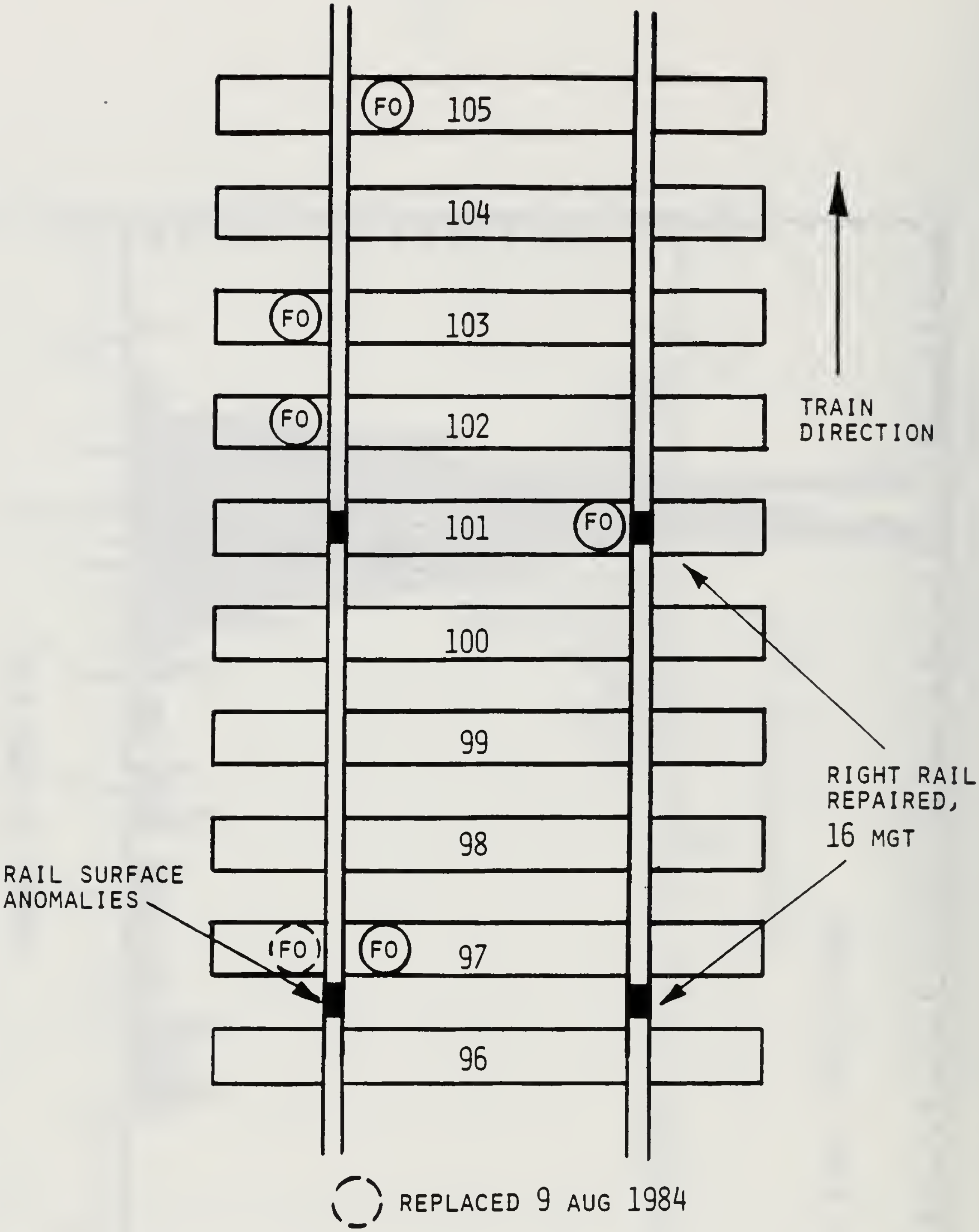


FIGURE 9. VERTICAL LOAD HISTOGRAM WITH DEEPER (.080") SIMULATED ENGINE BURN -- 4 MGT DATA



FASTENER FALLOUT PATTERN AT 0.080" DIVOTS,
SECTION 22 CONCRETE TIE TRACK (AAR/TTC)

FIGURE 10. TRACK COMPONENT DEGRADATION PATTERN WITHIN IMPACT TEST SITE, SECTION 22, AT 18 MGT

deflections recorded along with load. These tests were conducted first with the track as found, then with 3, 11 and 18 clip-pairs and insulators of the inside (left) rail removed symmetrically about the point of load application. A maximum of 18 fasteners were removed instead of the 21 planned, since the interior wheelsets of the 605 car interferred with removing additional clips.

Typical railhead lateral force/deflection curves from these track strength tests are shown in Figure 11. For comparison, test results from similar measurements from 1979 on the TTC Railroad Test Track wood-tie, cut-spike track are shown in the dashed curve. Nominal deflection characteristics of the wood-tie track are seen to be equivalent to the NEC concrete-tie track with 3 clip-pairs/insulators missing in a row. These tests showed that with an exceptional 11 to 18 clip-pairs/insulators missing, the rail was still retained within safe gage-widening limits by the shoulder/inserts of NEC track configuration.

Rail buckling stability tests were next addressed. It was found that the rail neutral (stress-free) temperature was between 86 and 90 F, so that a sufficient thermal buckling load could not be attained. The rail was then cut during the early-morning hours and loosened, and the rail rewelded to achieve a lower neutral temperature. From longitudinal strain gage readings, the final stress-free temperature was between 65 and 68 F. Tests then depended upon local weather conditions. With prevailing mild weather during the week of the tests, rail temperature in direct sunlight seldom exceeded 110 F. Tests were finally conduct ed at a rail temperature between 109 and 112 F. The 605 car was pulled back from the site, the approached slowly with the 18 clip-pairs/insulators missing. No rail instability was observed: the rail tended to move inward toward the gage-side shoulder/inserts in the center part of the missing fastener pattern, but was not in firm contact. Jogging the rail outward with a lining bar, once the 605 car had been moved back, also did not produce any signs of instability. It was felt at this point that removing shoulder/inserts would have little bearing on the test results and would artifically damage the test section. Therefore the track strength tests were terminated.

Analytical Model Validation

The nonlinear finite-element model of the track, Program RAILDEF, was validated by comparing predicted rail deflections with the results from the TTC track strength tests. The model was restructured to some degree to simulate more accurately the individual fasteners. Track components at the point of load application are represented schematically in Figure 12. Fasteners more distant from this point are represented by progressively more simple models up to the boundary with undisturbed track. This point was assumed to be 20 ft in either direction from the load point.

Comparisons of rail head and rail base lateral deflections under combined vertical and lateral loads predicted by RAILDEF and measured in tests are given in Figures 13 and 14. Predicted results are generally conservative in that slightly more deflection is computed for a given load than the tests show. Parameters for the model were based on a combination of laboratory tests of individual components and manufacturers' catalog data.

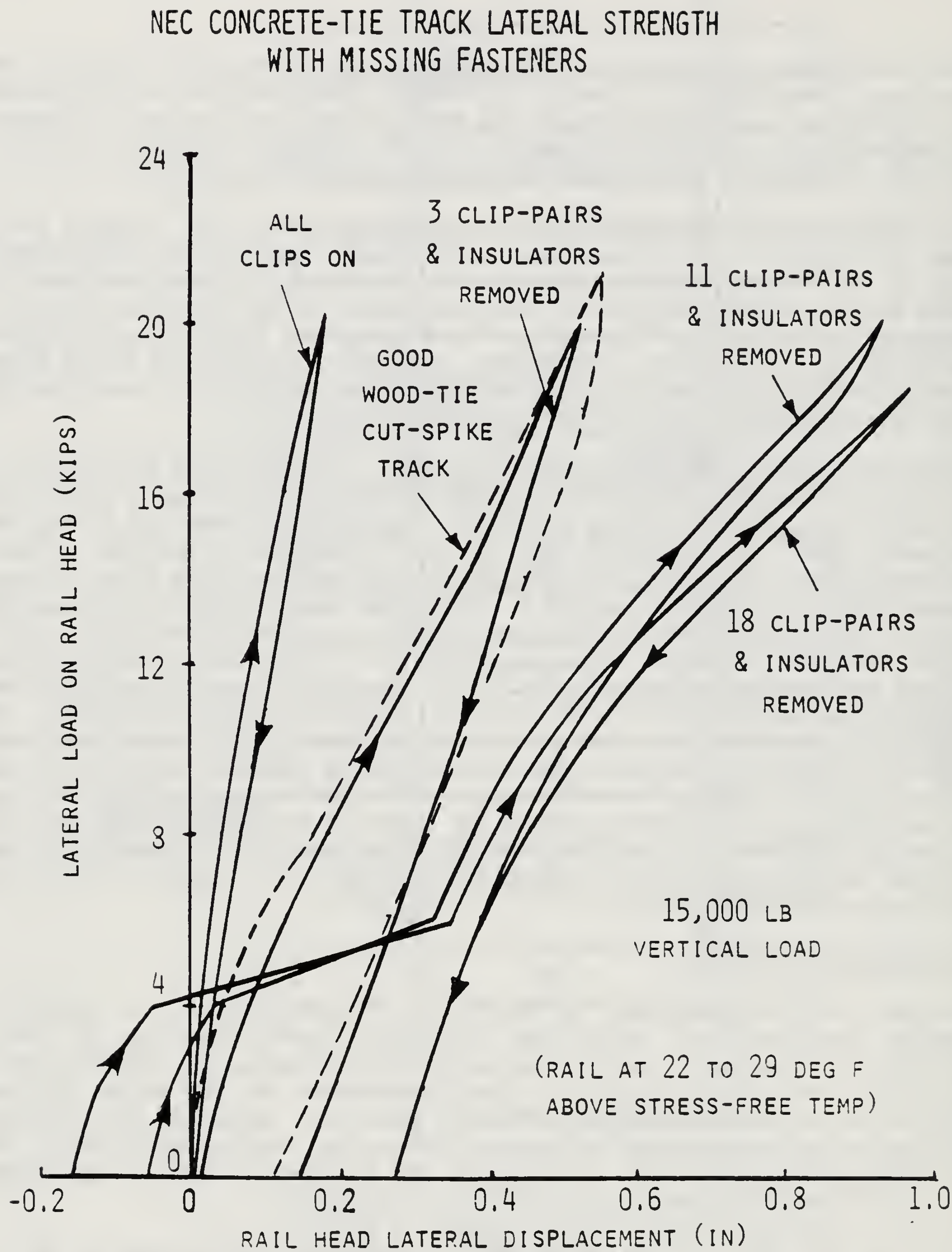


FIGURE 11. RESULTS OF TRACK STRENGTH MEASUREMENTS ON NEC CONCRETE TIE TRACK STRUCTURE -- SECTION 22, TRANSPORTATION TEST CENTER FAST TRACK LOOP

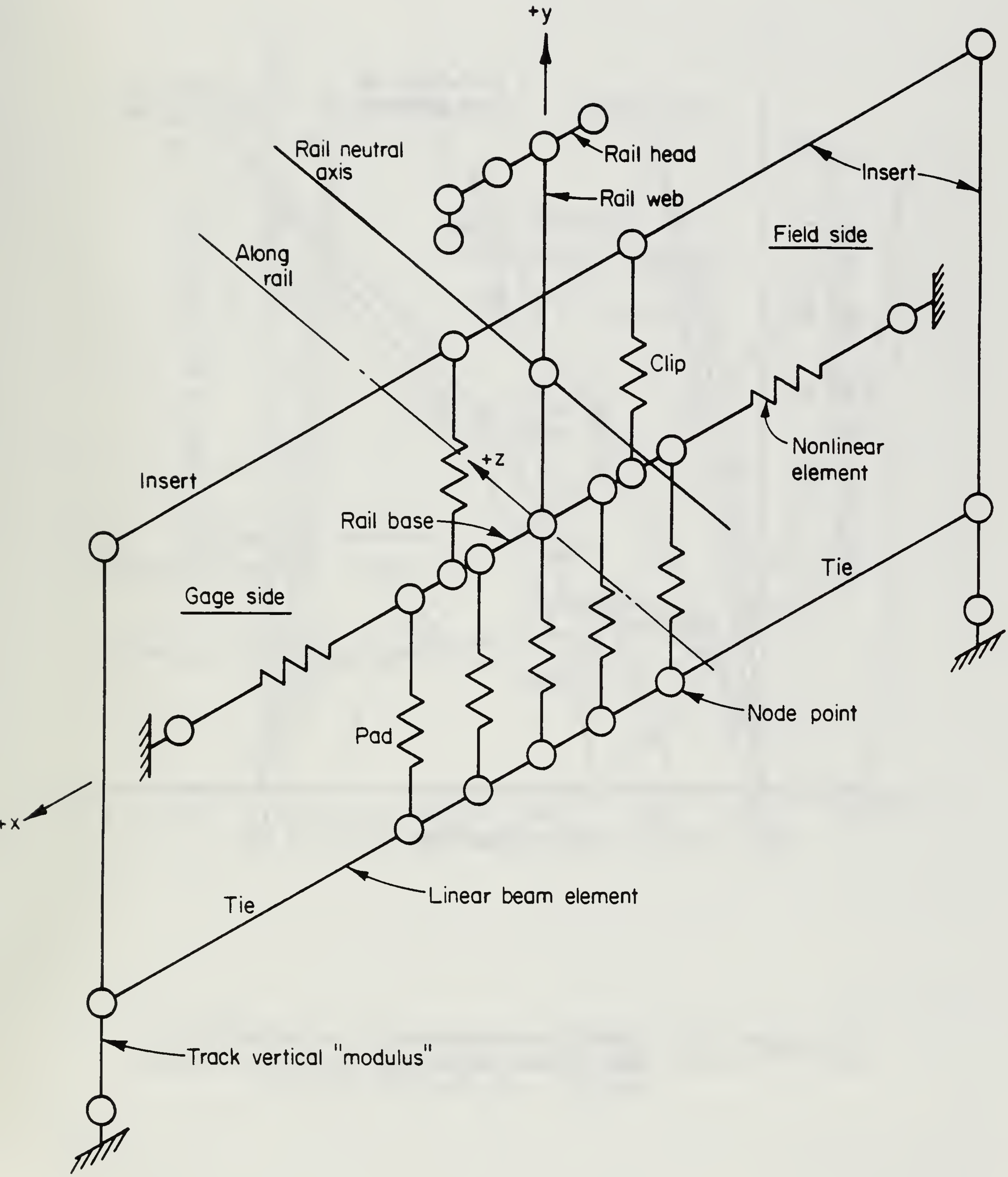


FIGURE 12 . PROGRAM "RAILDEF" -- REPRESENTATION OF TRACK COMPONENTS (RAIL, FASTENERS, PAD, ETC.) AT POINT OF LATERAL AND VERTICAL LOAD APPLICATION

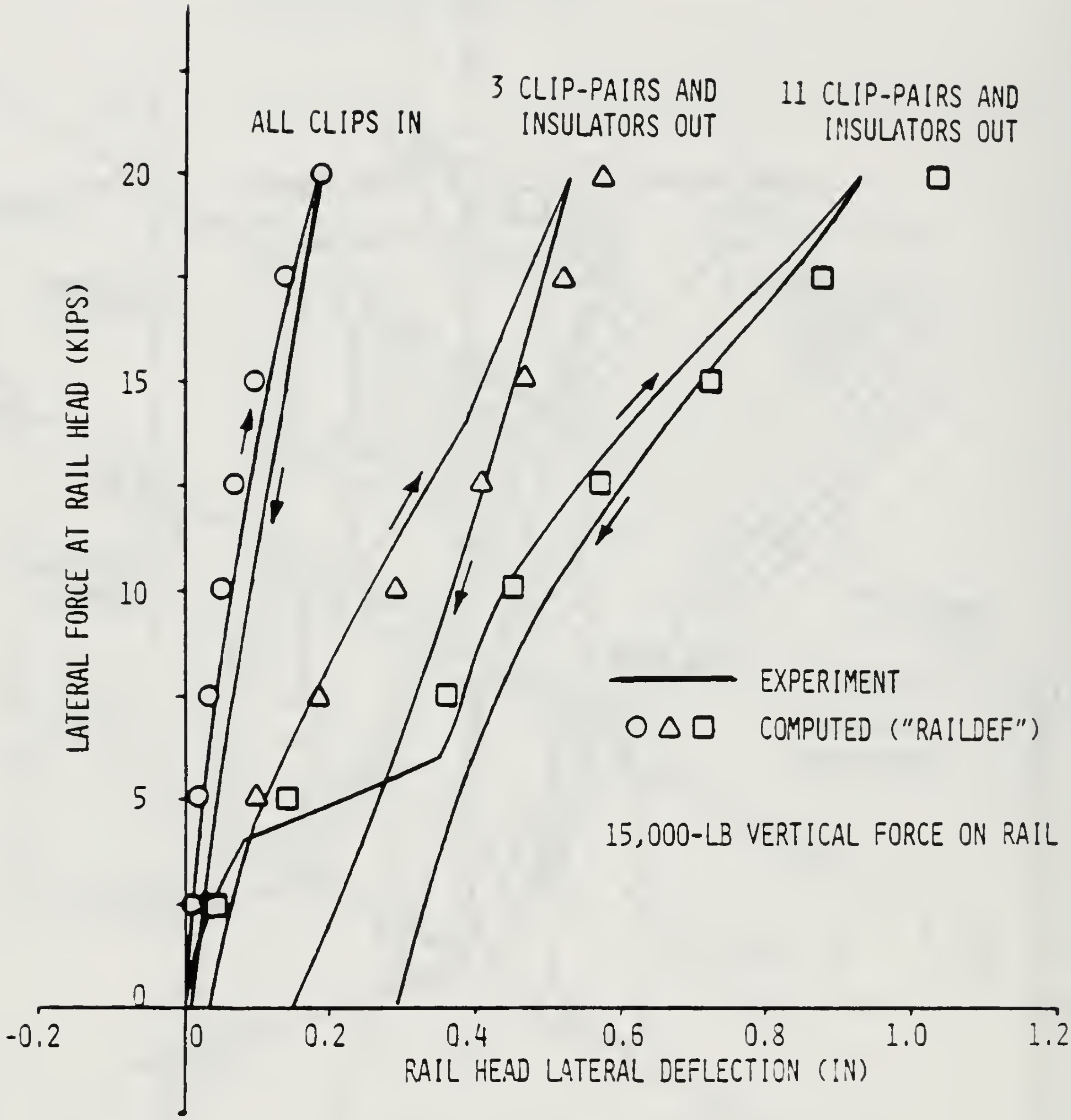


FIGURE 13. COMPARISON OF PREDICTED WITH MEASURED RAIL HEAD LATERAL DEFLECTIONS WITH RAIL FASTENERS REMOVED -- NEC CONCRETE TIE TRACK

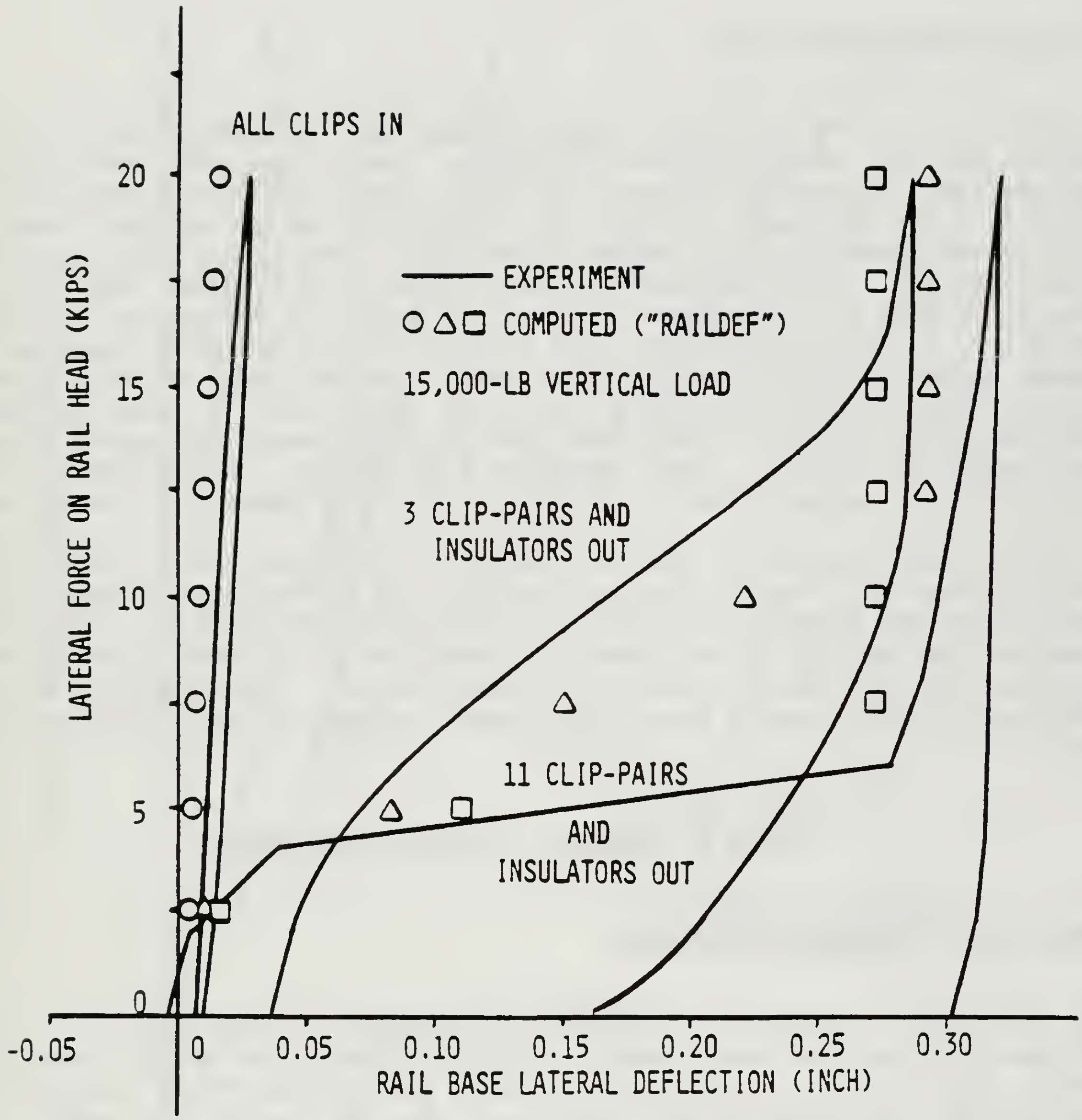


FIGURE 14 . COMPARISON OF PREDICTED WITH MEASURED RAIL BASE DEFLECTIONS -- NEC CONCRETE TIE TRACK

Track Strength Predictions

Verification of the analytical model RAILDEF then allowed predictions of rail deflections with shoulder/inserts missing. Predictions with several different combinations of missing fasteners (clip-pairs and insulators) and shoulder inserts in a row are shown in Figure 15. The predicted deflections form a "tree" with curves branching at different points as clearances are taken up and shoulders contacted. The rather extreme combination of 11 fasteners and 7 shoulder/-inserts missing in a row shows less than 1.5 inches of deflection for L/V ration below 1.2, a value normally produced for only very short time durations. This amount of gage widening, assuming the load on one rail only (which is expected on tangent track) would not cause a wheel-drop derailment. It must be emphasized that these predictions and the track strength tests represent loading to expected worst-case L/V ratios. Track geometry measurements, on the other hand, are conducted with nominally-small lateral loads on the geometry car wheelsets.

A similar verification of the nonlinear rail buckling model TBTRACK was not possible from test results. Several combinations of missing fasteners and shoulder/inserts are examined in the predictive curves of Figure 16. Note that rail buckling instability is not predicted even for 11 fasteners and 7 shoulders missing, and the maximum Class 6 alignment error. Removing just a few more shoulders, however, would result in a rapid increase in deflection with thermal load.

Task 3. Remedial Projects Assignment

Wheel Impact Detector Performance

The Wheel Impact Detector at Edgewood, Maryland has worked reliably for the past six months since the replacement of a faulty amplifier in the communications modem. Load statistics have been routinely gathered by AMTRAK and the FRA, and the results have shown stable load levels for the freight car wheels of 0.14 percent, and for passenger car wheels of 0.05 percent of total events exceeding the 60,000 lb level, based on a four-week running average.

A recent check of wheel loads under passing Amfleet equipment showed that the impact loads due to the "engine burn" over Circuit #3 has remained stable. The impact factor under passenger equipment at high speed has risen from 1.72 in October 1983, 1.84 in May 1984, to 1.83 in March 1985. The impact factor under the AEM-7 locomotive wheels is a lower 1.65 due to the larger wheel diameter.

Some investigations have been conducted by the NECIP staff to correlate the impact load data from the detector with specific types of freight traffic. Preliminary results of this work are shown in Table 13. These results indicate that wheel conditions on unit coal trains produce a greater share of impact load events on a percent per population basis than other types of equipment.

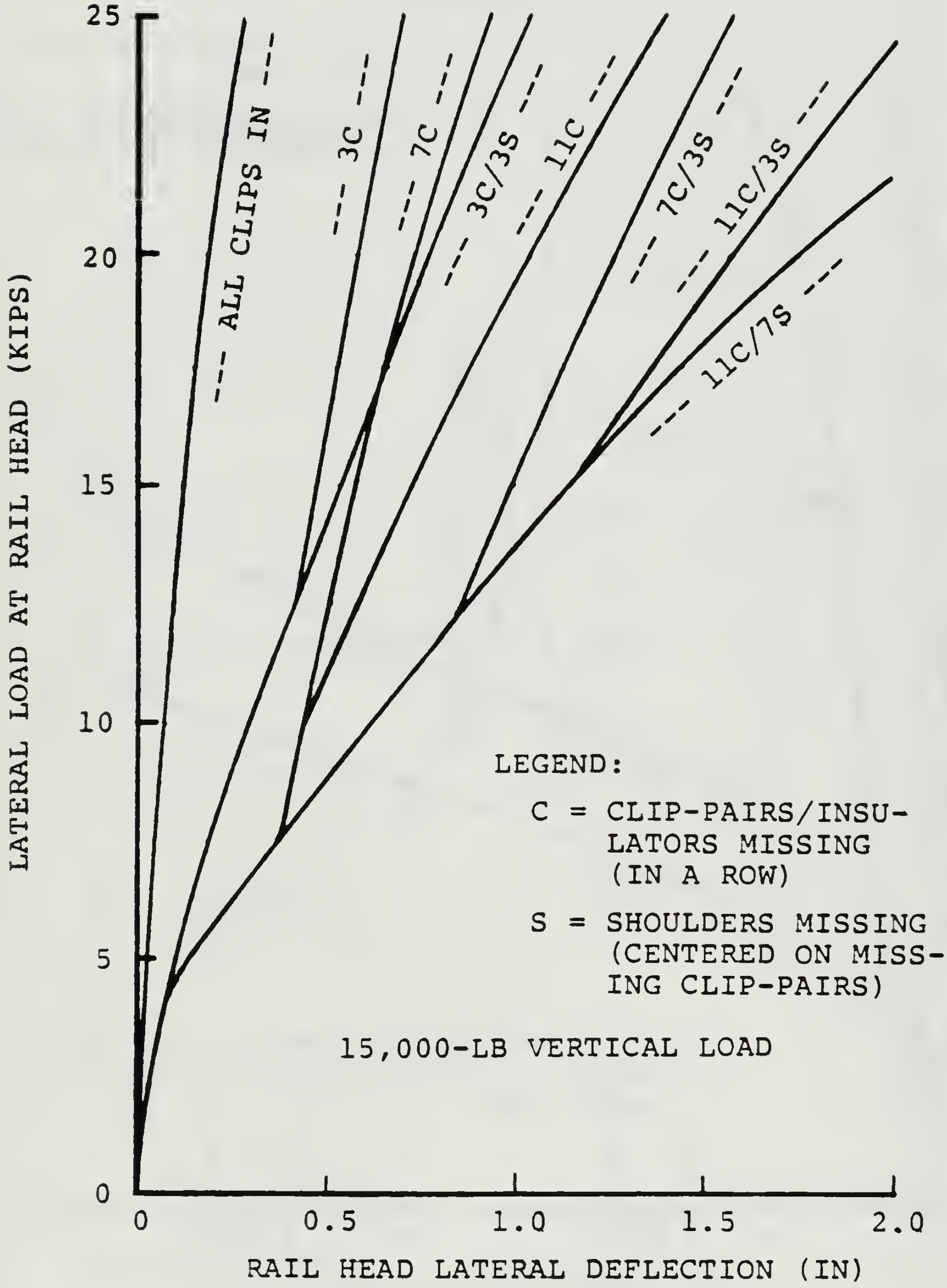


FIGURE 15. PREDICTED RAIL LATERAL DEFLECTIONS UNDER VERTICAL AND LATERAL WHEEL LOADS -- NEC CONCRETE TIE TRACK WITH MISSING FASTENERS AND SHOULDERS

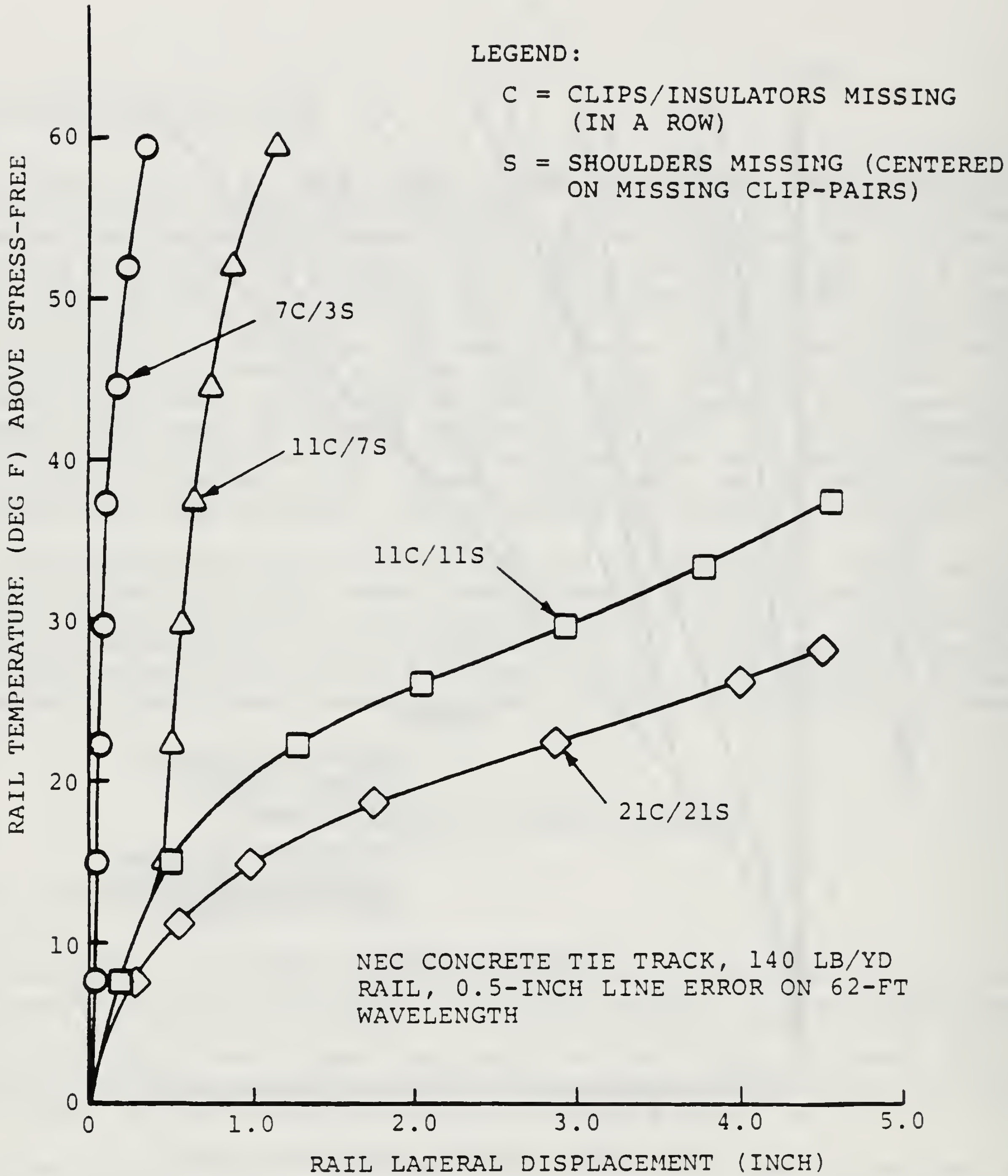


FIGURE 16. PREDICTED LATERAL DISPLACEMENT OF RAIL UNDER THERMAL LOAD -- CONCRETE TIE TRACK WITH MISSING FASTENERS AND SHOULDERS

TABLE 13. CORRELATION OF WHEEL IMPACT LOADS AT EDGEWOOD DETECTOR SITE WITH SPECIFIC TYPES OF FREIGHT TRAFFIC -- DATA FROM 4-2-84 to 4-30-84, 6-29-84 to 7-6-84

			SUMMARY OF EVENTS IN BAND					
CODE	TRAFFIC	AXLE COUNT	IMPACT LOAD BAND (KIPS)					
			50-59	60-69	70-79	80-89	90-99	100+
1	COAL - UNIT	8,222	60	39	18	17	5	3
2	GENERAL MERCHANDISE	18,604	53	25	14	4	1	3
3	TRAILER VAN	4,848	18	4	2	0	0	0
4	GRAIN - UNIT	1,008	15	5	3	1	1	1
5	MISC - WORK TRAINS, ETC.	236	0	0	0	0	0	0
6	UNKNOWN	1,806	10	9	5	1	2	0
	TOTALS	34,724	156	82	42	23	9	7

			SUMMARY OF PERCENT IN BAND					
CODE	TRAFFIC	AXLE COUNT	IMPACT LOAD BAND (KIPS)					
			50-59	60-69	70-79	80-89	90-99	100+
1	COAL - UNIT	24	38	48	43	74	56	43
2	GENERAL MERCHANDISE	54	34	30	33	17	11	43
3	TRAILER VAN	14	12	5	5	0	0	0
4	GRAIN - UNIT	3	10	6	7	4	11	14
5	MISC - WORK TRAINS, ETC.							
6	UNKNOWN	5	6	11	12	4	22	0
	TOTALS	100	100	100	100	100	100	100

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